Pushing the limits of lithography for IC production

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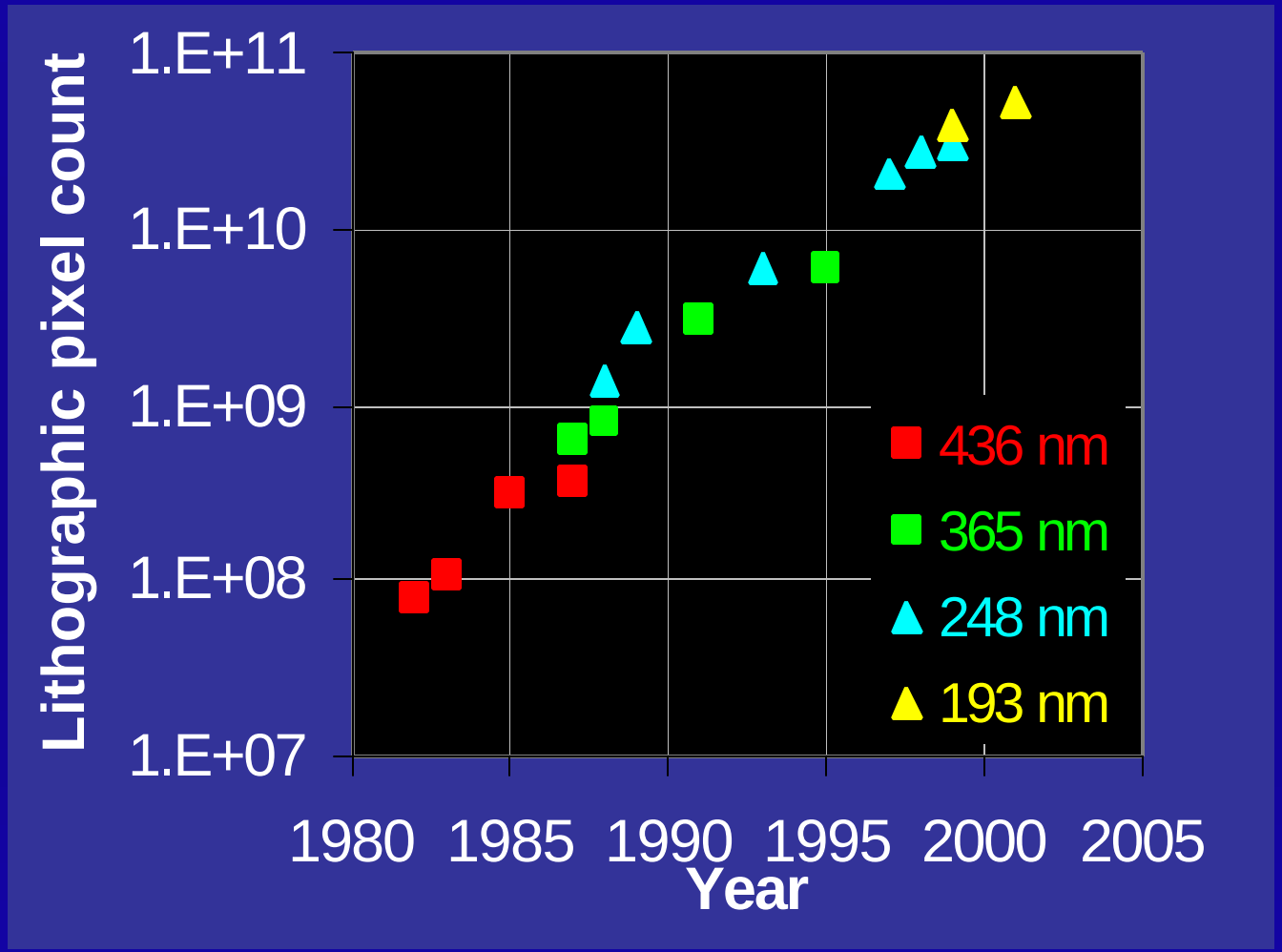
Progress of Litho Optics



Three Ways to Improve Resolution

$$W_{min} = k_1 \lambda / NA$$

Reduce λ

Reduce k_1

Increase NA

Significant Litho Wavelengths

Source	l	Dl/l	W_{min}	DOF
G-line	436nm		249nm	850nm
I-line	365	19%	209	730
KrF	248	47	142	500
ArF	193	28	110	400
F_2 ?	157	23	90	320
Ar_2 ??	126	25	72	257

W_{min} assumes $k_1 = 0.4$ and NA=0.7

Rayleigh DO = λ/NA^2

Optical Lithography at λ<193nm

- **MIT LL research to explore 157nm**
  - **Severe optical material issues**
    - **Transmissive photomask (CaF_2) has severe thermal stability problems**
      - Fused silica 0.5ppm/°C
      - CaF_2 substrate 19ppm/°C
  - **Resist process, dry N_2 atmosphere, F_2 laser, etc.**
  - **Unlikely to meet SIA roadmap for 100nm in 2003**
- **126nm Ar_2 lamp source??**
  - **Currently 100X too weak**
  - **No good lens material forces all-reflective optics**
  - **Prospects remote**

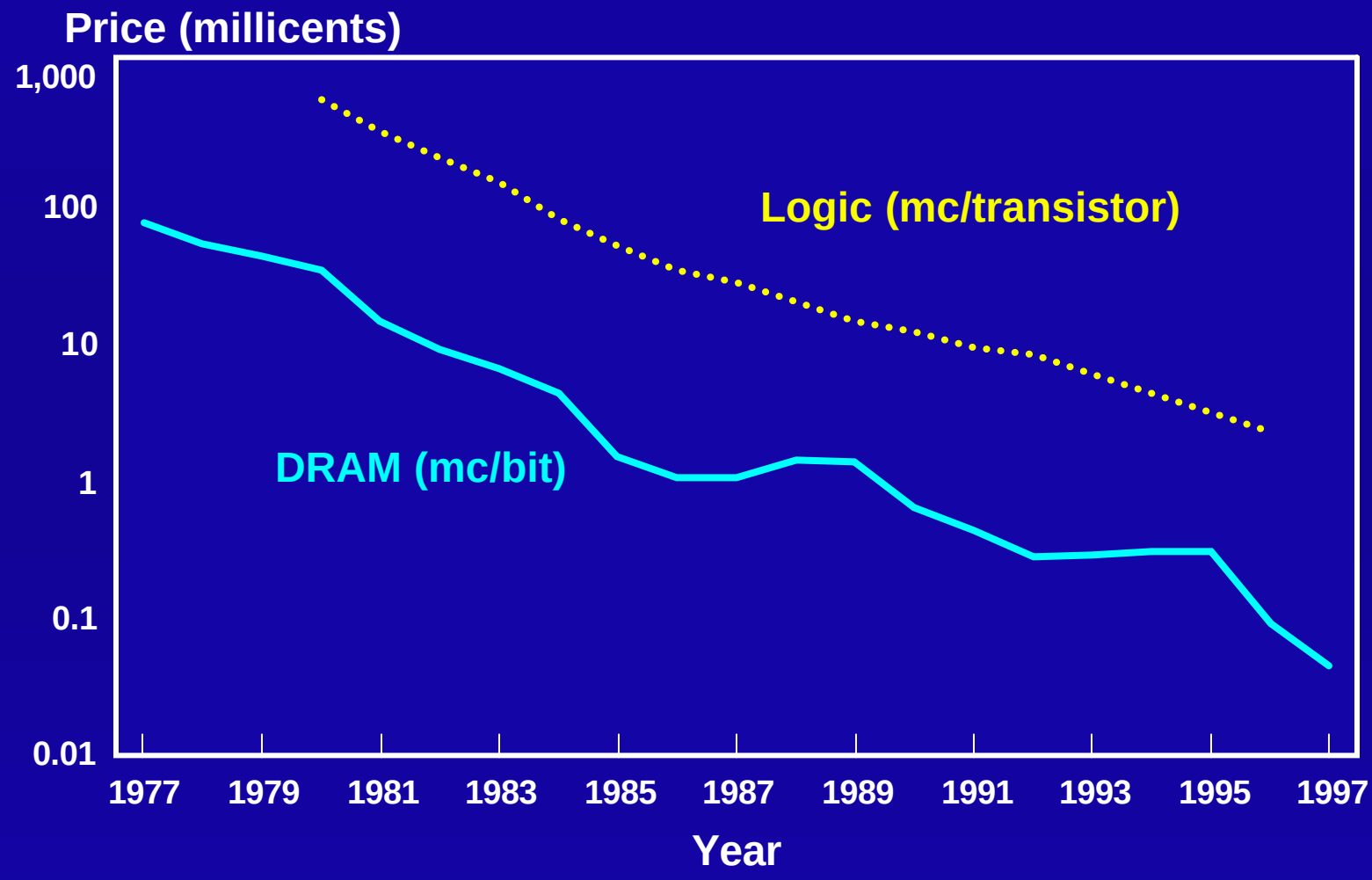
Conventional vs. Advanced Imaging

- Conventional imaging, OK for k_1>0.65
  - COG mask same as desired pattern
  - Stepper optics are fixed at standard NA and s
  - Simple to understand and implement!
- Advanced imaging, needed for k_1<0.65
  - Optical Proximity Correction (OPC) - predistort mask pattern to account for process
  - Use Phase Shift Mask (PSM)? What type of PSM?
  - Vary optics settings? NA and illumination.
    - Off Axis Illumination (OAI)?
  - Much more complicated!
  - Simulations necessary for finding optimal printing

Major “Post-optical” Candidates

- EUV - Extreme UltraViolet λ=13nm projector
  - All-reflective optics and mask using multi-layers
- Ion beam projection using 100kV ions
  - Stencil mask
- SCALPEL - 100kV electron projection
  - Membrane mask with patterned scatterer
- X-ray proximity printing with narrow mask/wafer gap
  - 1X membrane masks with high-Z absorber

Price Trends



Source: ICE
Courtesy: M. Cowan, IBM